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SUPERVISORY CONTROL INFORMATION MANAGEMENT RESEARCH (SCIMR)

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AFRL-RH-WP-TR-2013-0066 HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION IN ACCORDANCE WITH ASSIGNED DISTRIBUTION STATEMENT.

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14. ABSTRACT
Advances in automation technologies and their application in supervisory control systems such and unmanned vehicles places an increased demand on the information provided to the supervising operator and the manner in which that information is presented and accessed. The Supervisory Control Information Management Research program was initiated to investigate the issues associated with the role information plays in the coordination of supervisory control systems. A series of investigative studies were conducted focusing on four key aspects of information management that have emerged in the context of ongoing supervisory control systems development, particularly unmanned aerial vehicles. These four key areas include: Mission and Sensor Management, Information Scalability, Information Visualization and Multi-Modal Interfaces. The current report documents the results and findings of these studies and their implications for future supervisory control interface research and development.

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PREFACE

This report describes activities performed during the development of interface technologies designed to improve supervisory control of multiple information sources (711 HPW/RHCI), Work Unit 71840919, Supervisory Control Information Management Research (SCIMR). The authors thank the entire SCIMR team to include Mr. Antonio Ayala, Dr. Guy French, Dr. Thomas Carretta, Dr. Kristen Liggett, Mr. James Boyer, Mrs. Sarah Lampke, Mr. Jimmy Whalen, Mr. Jason Roll, Mr. Brian Donnelly, Ms. Hannah Combs, and Mr. Sohom Manna.

1.0 INTRODUCTION

Since its inception, the Remotely Piloted Aircraft (RPA) has adapted to military life and has subsequently become an integral part of modern day warfare. Although unmanned, this technology remains dependent on human interaction for optimal function. The Supervisory Control Information Management Research (**SCIMR**) program sought to explore, develop, and evaluate novel information management tools such as controls, displays, and decision support aids for the supervisory control of multiple RPAs. The multiple research efforts conducted to accomplish this goal fall into four categories**; Mission and Sensor Management, Information Scalability, Advanced Visualization, and Multi-Modal Interfaces**

The SCIMR program resulted in 9 conference papers and 4 technical reports.

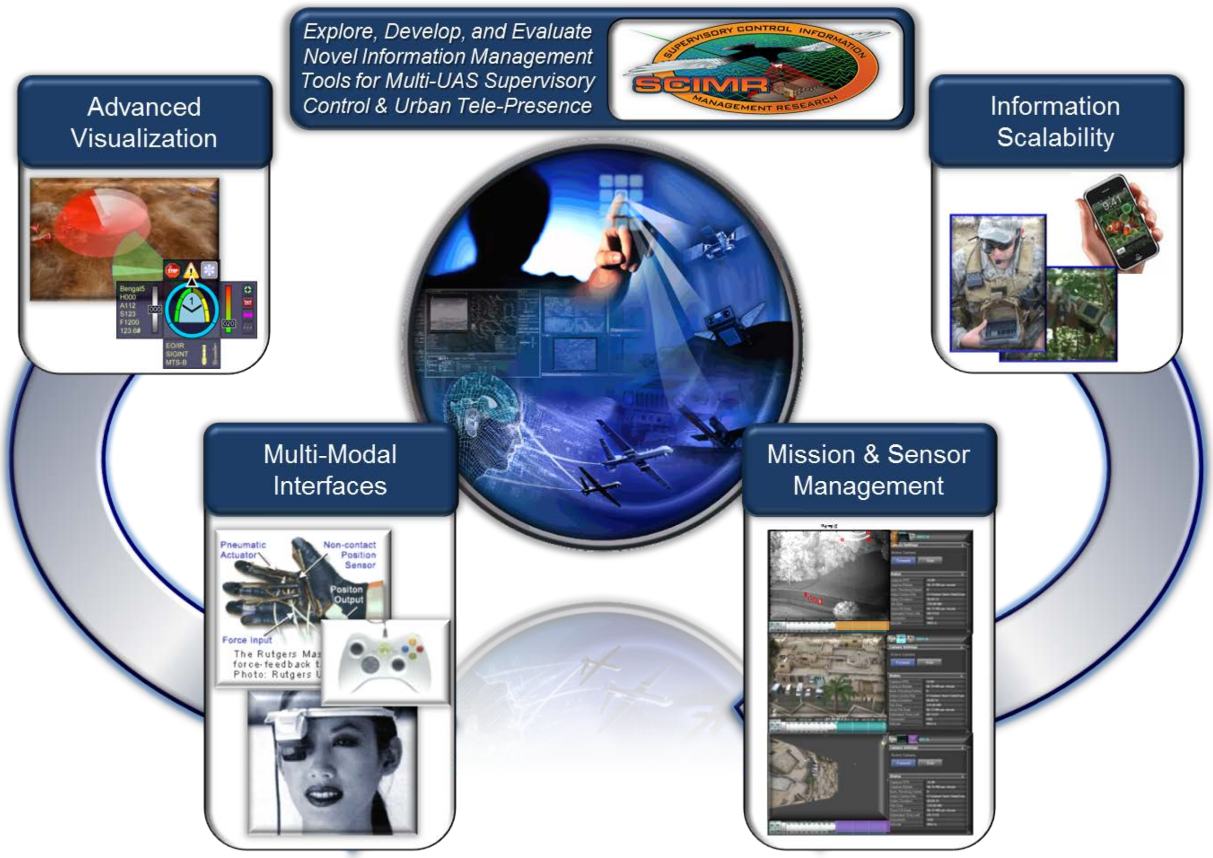


Figure 1. Four Research Areas of SCIMR

2.0 SUMMARY OF COMPLETED EXPERIMENTS

2.1 Mission and Sensor Management

This set of the SCIMR studies developed and tested advance interface concepts to support target detection, classification, and prioritization for operators monitoring multiple video streams.

2.1.1 Vigilant spirit control station: A research testbed for multi-UAS supervisory control interfaces

Introduction

Bridging the gap between rapidly advancing technology and the human, the Vigilant Spirit Control Station (VSCS) serves as a multi-faceted facilitator in areas ranging from research to combat missions. The result, consequentially, is an increase in the efficiency of the program by enabling a single operator to supervise multiple vehicles. Streamlining technology is tantamount to the program's success. Developed with this in mind, VSCS effectively integrates sophisticated advancements for the purpose of strengthening the collaborative relationship between the operator and the UAV, and ultimately serves to propel this multi-purpose asset into the next decade.

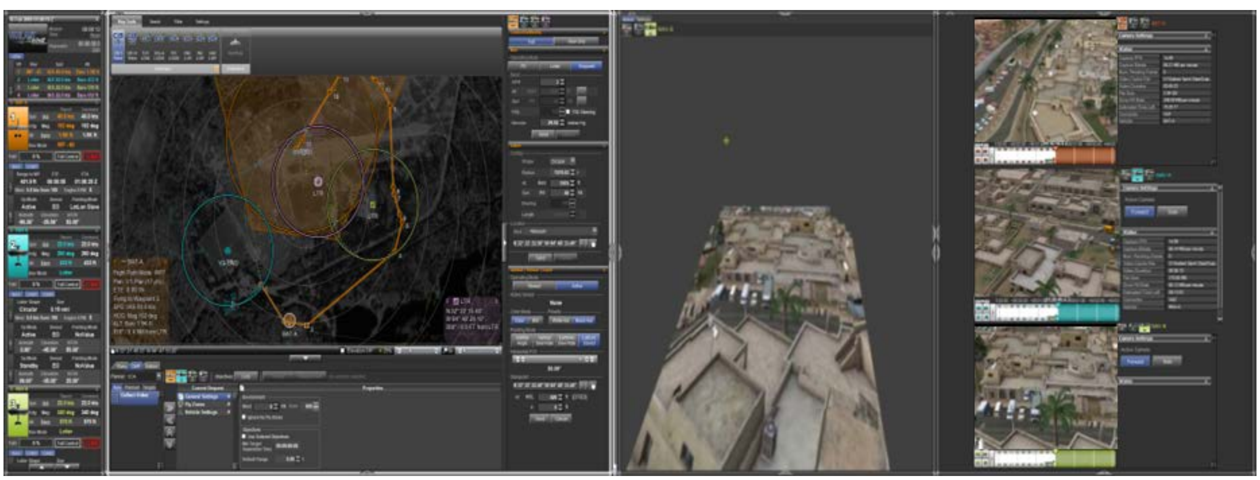


Figure 2: Screen Shot of a Typical VSCS Configuration.

Publications

Rowe, A. J., & Davis, J. E. (2009). Vigilant spirit control station: A research testbed for multi-UAS supervisory control interfaces. *Proceedings of the fifteenth International Symposium on Aviation Psychology*, Dayton, OH, pp. 287-292.

2.1.2 Effects of Video Display Format, Video Frame Rate, and Target Alerting on Target Designation Study

Introduction

The use of small remotely piloted aircraft to support military reconnaissance, surveillance, and target acquisition (RSTA) operations is becoming increasingly widespread. RSTA tasks require a human operator to continuously monitor information from the vehicles′ sensors and detect potential targets. This is especially problematic when an operator must divide attention between two or more videos. The current study examined the effect of video display format, frame rate, and target alerting on several objective and subjective performance measures.

Methods

The study had 2 parts. Part 1 examined the effects of video display mode, frame rate, and target alerting level on target acquisition performance. Part 2 examined subjective impressions of the image quality/interpretability of the different display formats.

A total of 16 participants used a version of the Vigilant Spirit Control Station (VSCS), set up to Monitor two UAV sensor feeds under the experimental conditions. These feeds were simulated using a commercial off the shelf product from MetaVR called the Virtual Reality Scene Generator (VRSG). Both task performance and questionnaire data were collected.

The Task Performance Measures of Number of Hits, Number of Misses, and Number of False Alarms are self-explanatory. These were collected for all study conditions. Three additional measures were available only for the conditions where target alerting was provided: False Cue Misses, Correct Rejections, and Incorrect Rejections. False Cue Misses occurred when the target alert indicated an object that was not a target and the participant did not detect the error. Correct Rejections occurred when the target alert indicated a non-target and the participant correctly rejected the alert. Incorrect Rejections occurred when the target alert correctly indicated a target and the participant incorrectly rejected the alert.

Each test trial lasted approximately 10 minutes. At the beginning of each trial the experimenter was responsible for commanding the simulated aircraft to begin road surveillance. When the aircraft arrived at the starting location, the experimenter verbally told the participant that the trial has started. Participants were then responsible for designating targets and responding to alerts, depending on the experimental condition. When the aircraft arrived at the end location the experimenter verbally notified the participant that the trial had ended. Subjective workload and usability assessment data was collected by questionnaires following each trial. After completion of all trials, participants evaluated the image quality/interpretability for the different presentation formats. This was done to determine subjective preferences for the formats and to illuminate whether perceptions of the formats were related to objective performance.

Conclusion

The goals of the study were to 1) examine human-system interface (HSI) display factors that may affect the performance of UAV MPOs doing a RSTA task requiring sustained attention and 2) develop HSI design recommendations to enable human operators to remain focused and alert in order to mitigate performance decrements often observed over prolonged periods. Results indicated that for the objective measures of target acquisition performance and subjective workload, there was no clear benefit to be gained from a mosaic display format or a high frame rate. A reliable target alert clearly enhanced target acquisition performance. Problems with the way the mosaic display format was implemented may have contributed to its unexpected poor performance. Additional studies are needed to examine the effectiveness of these display factors under more realistic conditions. These studies should employ a longer duration task to examine performance decrements over prolonged periods, use a wider range of target types (e.g., moving and still targets) and settings (e.g., rural, suburban, and urban), and additional measures of image quality/interpretability (e.g., Video National Imagery Interpretability Rating Scales). Other studies should be performed to examine the utility of video and image enhancement techniques for improving the interpretability of video imagery. Some examples are algorithms involving stabilization, deblurring, dehazing, super-resolution, and object tracking.

Publications

Carretta, T. R., Ayala, A., French G. A., Gonzalez-Garcia, A., Liggett, K. K., Rowe, A. J., Wright, N. F., & Flach, J. K. (2009). *Effects of video display format, video frame rate, and target alerting on target detection performance in a simulated environment*, AFRL-RH-WP-TR-2010-0042. Wright-Patterson AFB, OH: Air Force Research Laboratory, Human Effectiveness Directorate, Crew Systems Interface Division, Supervisory Control Interfaces Branch.

Carretta, T. R., Rowe, A. J., & Flach, J. K. (2010). *Effects of Video Display Format, Video Frame Rate, and Target Alerting on Target Designation.* Proceedings of the HCI-Aero conference, Cape Canaveral, FL.

2.1.3 Vigilance Decrements in a Sustained Attention Task: Examination of a Mitigation Strategy: Study 1

Introduction

A study was conducted to examine the effectiveness of perceptual and cognitive intervention tasks on mitigating vigilance decrements commonly observed in sustained attention tasks. Sixteen participants were randomly assigned to one of two experimental intervention conditions (perceptual or cognitive). Half of the participants completed a 45-minute "No Intervention" Control trial first, followed by one of the Intervention trials, also 45 minutes. The other half completed one of the Intervention trials first, followed by the No intervention trial. Following each trial, participants completed the SSSQ and the NASA TLX.

Methods

Several types of data were collected. These included objective measures of perceptual vigilance ability and target acquisition performance (hits, misses, false alarms), demographic/background data, and subjective measures of mood/stress and workload.

The study began with a pre-briefing regarding research objectives, procedures and informed consent. This was followed by administration of the Demographic Data Questionnaire. Next, participants completed an abbreviated version of the Dundee Stress State Questionnaire (DSSQ) called the Short Stress State Questionnaire (SSSQ) to establish a baseline of their stress level. Next, the 12-minute Perceptual Vigilance Task (PVT) was administered to estimate participants' perceptual vigilance ability. Scores from the baseline PVT were correlated with objective measures of performance on the experimental task to examine relations between the tasks. Following the short vigilance task, participants completed the SSSQ to assess changes from their baseline (pre-vigilance task) level. They also completed the NASA TLX to assess subjective workload. There was a 10-minute break following completion of the PVT and questionnaires.

Next, participants were randomly assigned to one of the two experimental intervention conditions (perceptual or cognitive). Half of them completed the "No Intervention" trial first, followed by one of the Intervention trials. The other half completed one of the Intervention trials first, followed by the No intervention trial. Following each target acquisition block, participants completed the SSSQ and the NASA TLX.

Those doing the No Intervention trial first completed a 3-minute practice session during which the target was 3 times more frequent than during the actual experiment. Task performance feedback was provided (i.e., hits, misses, and false alarms) during the practice trial. After a short break, the 45-minute experimental trial followed during which no performance feedback was given. Following the experimental trial, participants completed the post-trial SSSQ and NASA TLX to assess their subjective stress and workload, then took a 10-minute break before beginning the second experimental session. The procedures were similar for the Intervention conditions. For these conditions, participants began with a 3-minute practice session during which the targets occurred 3 times more frequently than in the experimental session. During the practice session, participants received feedback on target acquisition performance (i.e., hits, misses, and false alarms) and the intervention occurred 6 times. After a short break, participants completed a 45-minute experimental trial during which no performance feedback was given. The post-test SSSQ and NASA TLX were completed following the experimental session to assess participants' subjective stress (mood state) and workload.

The experimental task was to monitor simulated video feeds from 2 remote fixed sensors positioned to monitor traffic intersections in an urban setting and to designate targets/suspicious behaviors as they were detected. Participants were instructed to designate targets and respond to interventions, depending on the experimental condition. Figures X illustrates the displayed imagery as viewed by study participants. Each screen (left and right) displayed information for one of the two remote sensors.

Figure 3: Displayed Imagery as Viewed by Study Participants.

Discussion

As expected, a general decrease in objective performance over time was observed. However, contrary to expectations and prior research (St. John & Risser, 2007), the experimental intervention tasks did not reduce decrements in target acquisition performance over time, nor did they reduce subjective workload. Methodological differences between the St. John and Risser study and the current study that may have contributed to differences in the effectiveness of the vigilance mitigation interventions in the two studies is the intervention schedule. St. John and Risser implemented their interventions with simulated psychophysiological monitoring where the intervention was triggered by a missed target. In the present study, a simpler approach was taken by implementing a constrained randomized schedule. Such an approach, if effective, would eliminate the need for physiological monitoring to achieve performance benefits. Alas, the current study indicated that such hopes were unjustified. Whether the reason for different results lies in the differences in the nature of the experimental tasks, the intervention schedule, or some interaction of the two, it appears at this point that physiological monitoring may be necessary to achieve the performance benefits of a system based mitigation strategy.

Publication:

French, G. A., Carretta, T. R., Flach, J. K. (2011). *Vigilance Decrements in a Sustained Attention Task: Examination of a Mitigation Strategy*. Proceedings of the sixteenth International Symposium on Aviation Psychology, Dayton, OH.

2.1.4 Mitigating the Effects of Vigilance Decrements: Study 2

Introduction

The objective of this study is to examine the impact of techniques designed to reduce the effects of vigilance decrements typically found in sustained attention tasks. The proposed research is a follow-up to study 1. SCIMR recently completed a study to examine the effectiveness of a secondary task on mitigating vigilance decrements in performance typically seen in tasks requiring sustained attention over long time intervals. The study design was based on procedures employed by St. John and Risser (2007) who examined the utility of perceptual and cognitive interventions for mitigating the vigilance decrement. Study 2 will examine the utility of a variable intervention schedule that mimics St John and Risser's (2009) physiological-based pattern. 1 additional study is planned. This study will replicate St. John and Risser (2009) with the addition of a no intervention control group to provide a baseline. If results of that study are consistent with St. John and Risser (2009), a second study will be performed using a more realistic RSTA task where a single operator is required to monitor sensor feeds from two remote sources.

Method

Several measures were collected prior to, during, and following the experimental target acquisition task. Objective measures of performance for the experimental task (ET) included proportion of hits and correct rejections, and number of false alarms.

During an Abbreviated perceptual vigilance task (AVT), participants monitored the presentation of 8- by 6-mm light grey capital letters that consisted of 'O', 'D', and a backwards 'D' centered on a video display screen. The letters were constructed in 24-point type using an AvantGarde font and were exposed for 40 milliseconds against a visual mask that consisted of unfilled circles on a white background. Participants were instructed to use the mouse to indicate when the target letter 'O' was presented. Responses were scored as hits, correct rejections, and false alarms.

NASA Task Load Index (NASA TLX), a subjective workload assessment measure that allows users to evaluate their interactions with human-machine systems was collected. A Short Stress State Questionnaire (SSSQ) was also collected. The SSSQ (Helton, 2004) is an abbreviated version of the Dundee Stress State Questionnaire (DSSQ). It consists of four subscales: mood state, motivation, thinking style, and thinking content. Scores for three factors are derived from the subscales: task engagement, distress, and worry. Additionally, one component of the SSSQ assesses participants' perceptions of their physical and mental workload. One version of the SSSQ was administered before task performance and the other was administered after task performance.

The study began with a pre-briefing regarding research objectives and procedures, informed consent, and collection of demographic data about factors that may be related to performance on the target detection task (e.g., age, gender, and experience with similar tasks). Participants then completed the SSSQ to provide a pre-study baseline of their stress level. Prior to examination of the effect of intervention schedule, a baseline was established for participants' perceptual vigilance using a 12 minute abbreviated vigilance task (AVT) based on a method described by Temple et al. (2000). These baseline data were used in the data analyses as a covariate to control for differences in perceptual vigilance among the study participants. Following the 12 minute AVT, participants completed the SSSQ to assess changes from their baseline (pre-study) level. They also completed the NASA TLX to assess their subjective workloads.

Participants were instructed to press the Space bar when they detected a target. Feedback was provided on hits, misses, and false alarms during the practice trial. After a short break, the 45-minute experimental trial followed during which performance feedback was given only for the intervention task . Following the experimental trial, participants completed the post-trial SSSQ and NASA TLX to assess their subjective stress (mood state) and workload.

The experimental task was identical to that used by St. John and Risser (2007, 2009). Participants monitored simulated snapshots from a Remotely Piloted Aircraft flying along a highway and were instructed to designate targets as they were detected. The event exposure duration was 400 ms and the event rate was 1 per 2 seconds with a critical signal (target) rate of three per minute. The critical signal was a truck icon that was slightly larger than the non-critical signal (110 pixels vs. 100 pixels). All signals occurred in one of 6 fixed screen locations. Participants were responsible for designating targets and responding to interventions, depending on the experimental condition. The experimental task lasted about 45 minutes.

Discussion

Contrary to St. John and Risser (2007), inclusion of a cognitive intervention did not improve performance beyond that observed for a No Intervention Control. Further, contrary to St. John and Risser (2009) the difference in performance for the Random and Physiologically-Based Intervention schedules was not statistically significant. St. John and Risser (2009) reported hit percentages of 64% and 70% for their Random and Physiologically-Based Intervention schedules compared with 61.4% and 65.0% in the current study. The relatively smaller improvement in the current study for the Physiologically-Based schedule may be because its implementation was not triggered by a missed target (St. John & Risser, 2007) or by indicators of fatigue/inattention (St. John & Risser, 2009). Even so, this does not explain why performance for the two intervention conditions was not better than that observed for the No Intervention Control (62.5%) condition in the current study. It is unknown whether the difference in results for St. John and Risser (2007, 2009) and French et al. (2011) and the current study lie in the trigger mechanism for the cognitive intervention. Implementation of a vigilance decrement mitigation intervention in an operational setting would be greatly facilitated if it were not required to link it with physiological indicators of inattention in order to achieve effectiveness. Regardless, the low correlations between scores on the abbreviated vigilance task and the experimental task suggest that they are not measuring the same constructs. (i.e., do not share construct validity). Further, the failure to replicate previous findings casts doubts on the robustness of the effectiveness of a simple cognitive intervention task for mitigating vigilance decrements in performance on real-world tasks that require sustained attention.

Publication

French, G. A., Carretta, T. R. (2012). Combating Vigilance Decrements in a Sustained Attention Task: Examination of Two Cognitive Intervention Schedules for a Secondary Task. Paper presented at Human Factors and Ergonomics Society Conference, Boston, MA.

Carretta, T.R., French G. A. (2012). Combating Vigilance Decrements in a Sustained Attention Task: Examination of Two Cognitive Intervention Schedules for a Secondary Task, AFRL-RH-WP-TR-2012-0172. Wright-Patterson AFB, OH: Air Force Research Laboratory, Human Effectiveness Directorate, Crew Systems Interface Division, Supervisory Control Interfaces Branch.

2.2 Information Scalability

This set of SCIMR studies focused on seamlessly compressing critical net-centric information onto man-portable interfaces

2.2.1 Pilot Study: The Potential Interface Issues Associated with Scaled Devices for the Control and Sensor Exploitation of Multiple Small Remotely Piloted Aircraft (RPA)

Introduction

As remotely piloted aircraft (RPAs) become more prevalent in the military theater and as these devices diminish in size and cost, the demand for control and sensor information to be presented on small man portable devices will increase. An RPA simulation environment was used to present participants with three devices of different scale, to elicit subjective feedback about interface concerns during a representative reconnaissance, surveillance, and target acquisition (RSTA) classification task. Participants performed the RSTA task with each of the scaled devices using two different, notional classification editor graphical user interfaces (GUIs). Participants were encouraged to talk aloud to identify potential problems and possible fixes to the scaled interfaces. Participants also completed a usability questionnaire and a workload assessment form after experiencing each device.

Methods

Participants were instructed to use 2 simulated RPAs to provide route surveillance. Participants were told which preloaded path to survey and then activate the Dynamic Path Surveillance System (DPSS). The DPSS automated vehicle and sensor control to maintain surveillance of the designated path. Participants were to monitor the sensor video feeds to identify objects of interest along the route. Objects could be either stationary or moving. Upon detection of an object of interest, participants were to bookmark the video and use one of two classification editors to classify, annotate, and assign a level of urgency for the selection. The editors differed in several ways including location on screen and information presentation. The two different classification editors and how they appeared on screen are shown in Figure X.

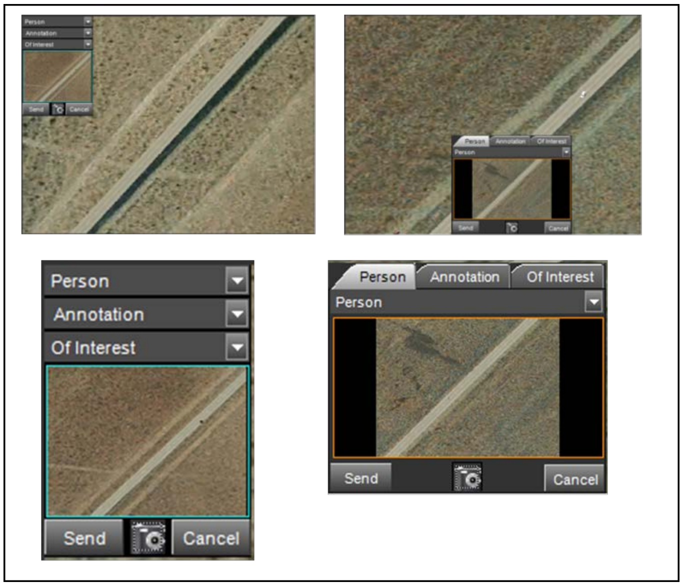


Figure 4: The Classification Editors

This task was repeated for each of the three interfaces. Participants were encouraged to talk aloud about likes, dislikes, and interface design issues. After each trial, the participants completed a questionnaire to rate the satisfaction and functionality of the interface as well as identifying the top problems and respective solutions.

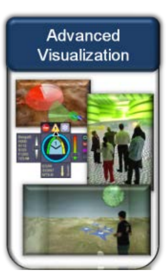
Discussion

This pilot study highlighted the need for future research into interfaces that will be used on small scale devices. Although the VSCS version used was not optimized for use on small devices, most participants thought that performing a RSTA mission with one or both of the scaled devices was feasible. Future studies will use some of the lessons learned from this study to help guide the design of control stations that will be run on smaller scaled devices.

Publication

None.

2.3 Advanced Visualization



This set of SCIMR studies investigated the utility of virtual reality technologies to support operator supervision of multiple vehicles while maximizing performance and decreasing vigilance decrements

2.3.1 Visual Awareness with Nemaline Target Accessibility Graphics Evaluation (VANTAGE) Studies

Introduction

As the capability to capture video and still imagery through sensors on remotely piloted aircraft (RPA) and fixed sensors continues to increase, the demands on the decision making abilities of the operators will also increase. While automation may eventually take some of the sensor monitoring load off of the operator, until then the burden of maintaining continuous over watch of a target will fall on the human operators. The VANTAGE studies are a series of 5 studies, all of which used the same basic task. The task required the participants to maintain a clear line of sight to a designated target. The target was walking around a generic Afghanistan urban environment. The participants had 2, 4, or 6 (depending on the experiment and treatment condition) remote piloted aircraft to keep track of the target with. The vehicles were flying in fixed orbits at about 1000 feet above ground level (AGL), which created obscurations. To help mitigate the obscurations created by the buildings augmented reality was used to show the user the target sensor relationship, specifically the rays shown in figure 5.

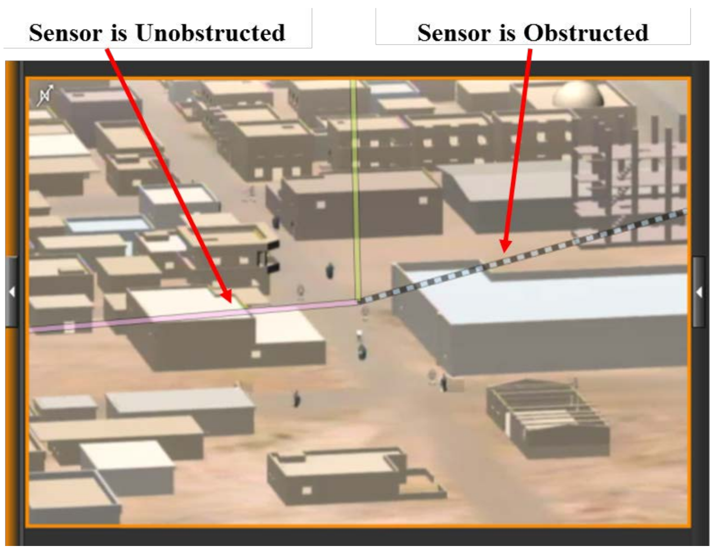


Figure 5: Synthetic Environment with Augmented Reality Overlay (Rays).

2.3.2 Predictive Continuous Vantage Study 1

Experiment Particulars

The participants were trying to maintain persistent stare on a stationary target (phase I) then on moving target (phase II) under varying ray conditions. The targets for both phases were in an urban environment, this caused the moving RPAs to at times lose line of sight to the target. The varied ray attributes were; ray color (on/off), ray mouse selectable (on/off), ray provides obstruction information (on/off) and ray thickness meaning (none, RPA distance from stare point, resolution of the sensor). The variations made twenty-four unique ray conditions. A baseline condition (no rays) was also investigated.

Discussion

Overall the best ray configuration was selectable colored rays. The combination led to an 11% increase in target ID accuracy during and the stationary phase and 3% increase in the percent of time the target was unoccluded. The number of good transitions (transitions to a sensor that had a clear line of sight to the target) was also greater in the selectable colored condition, however the total number of transitions also increased in this condition. Subjectively the moving target portion of the study was felt to be more difficult than the stationary target phase. The different mission phases will be more closely examined in future studies.

Publications

Rowe, A., Venero, P., & Boyer, J. (2012, June) *Improving Situation Awareness Through Enhanced Knowledge of Sensor Target Relationships.* Paper presented at Military Operations Society Symposium, Colorado Springs, CO.

2.3.3 Predictive Continuous Vantage Study 2A

Experiment Particulars

This study builds on the insight gained from 'Predictive Continuous Vantage Study 1', starting with target behavior. There will be no stationary targets in this study. In study 1 the sensor auto slewed to the target location at all times, in this study the participant had to manually slew the sensor. The number of ray conditions was down selected to three. The three ray conditions were none, solid, and dashed. Under the solid condition the rays were only colored and selectable. Under the dashed condition the rays were colored and selectable, but also provided obstruction information by going dashed when the line of sight was blocked. The other independent variable was Vigilant Spirit Control Station (VSCS) configuration, master screen only or master screen plus four individual screens for the sensors. There were some similarities between the two studies as well. In both studies the target is moving through an urban environment, and the participant has to choose one of four RPA sensor feeds to provide to an external customer.

Discussion

Preliminary results showed that the VSCS configuration independent variable had no effect on performance, however the ray configuration and target route did. The solid condition improves percent unoccluded by 7.8% and 3.8% when compared to the no ray condition and the dashed condition, respectively. The route that the target followed through the city also had an effect on the percent unoccluded. When looking at the unoccluded time span, again the VSCS configuration had no effect but the ray condition and target route did. The solid ray condition reduce unoccluded span by 2.2 seconds compared to the no ray condition. The dashed ray condition reduce unoccluded span by 1.7 seconds compared to the no ray condition. There was no difference between the solid and dashed conditions.

Publications

Venero, P., Rowe, A., and Boyer, J. (2012) *Using Augmented Reality to Help Maintain Persistent Stare of a Moving Target in an Urban Environment.* Paper presented at Human Factors and Ergonomics Society Conference, Boston, MA.

2.3.4 Predictive Continuous Vantage Study 2B

Experiment Particulars

Similar to what we had done in previous studies, we told the participants to provide the best possible sensor feed to a notional joint terminal area controller (JTAC) who was equipped with a small hand-held computer (similar to an Apple iPad) that can only consume one video at a time. In this scenario, the JTAC was relying on the participant to maintain a constant view of a high value individual (HVI). The HVI moved through an urban environment for approximately eight minutes, stopping twice per trial to converse with associates. The trial ended when the HVI entered a building. We randomly placed six RPAs in one of six predetermined starting positions, and they flew a predetermined route. Due the path of the target and the route of the RPAs, no one RPA had a clear line of sight to the target at all times. We gave the participants an introduction to the program, and they reviewed and signed the informed consent form. They then completed three training trials that we had designed to familiarize them with the task and the different aspects of the control station. After they had completed the training trials, they completed 12 data collection trials. After each trial, we administered questionnaires that assessed workload and situation awareness. The experiment had two independent variables: obstruction information presentation (OIP) and interface configuration. The OIP independent variable describes how we presented the obstruction information to the participant. The OIP independent variable had three levels: none (no obstruction information presented), timeline only (obstruction information presented through the timeline only), and timeline with rays (obstruction information presented through timeline and the vantage rays). The interface configuration independent variable determined whether or not the operator had dedicated screens for each of the sensors. Figure 3 shows an example of the map (A), master sensor screen (B), timeline (C), and the six dedicated sensor screens (D).

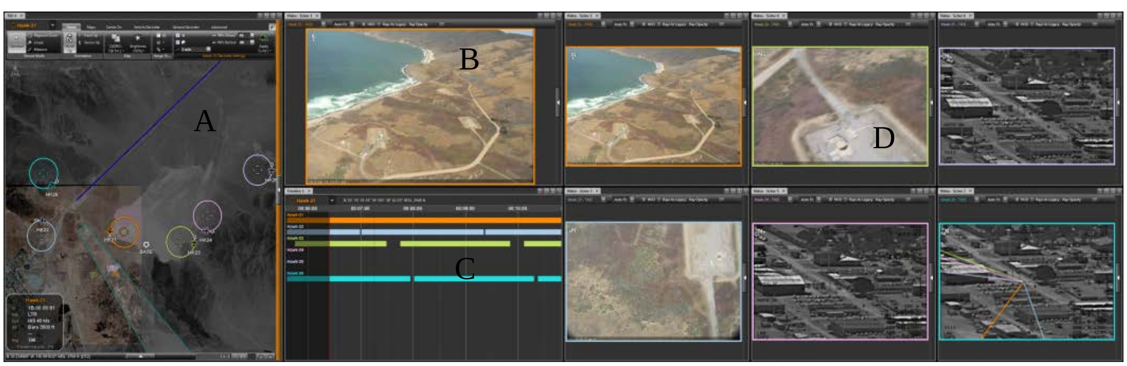


Figure 6: Sample Interface with; (A) Map (B) Master Sensor Screen, (C) Timeline, and (D) Six Dedicated Sensor Screens.

We collected objective and subjective measures to assess the participants' performance. We collected the following objective measures: percent unoccluded, average unoccluded time span, total number of transitions, and number of good transitions. The percent unoccluded was the amount of time the HVI was actually visible in the master sensor screen divided by the amount of time the HVI was potentially able to be seen in the master sensor screen. The average unoccluded time span was the average length of time the HVI was in the master sensor screen. The total number of transitions was a count of the number of times the participant switched sensors in the master sensor screen. The number of good transitions was a count of the number of times the participant switched sensors and was able to see the HVI in the new sensor. We also collected subjective measures for the operators' situation awareness and workload.

Discussion

The underlying belief behind the hypotheses was that the obstruction information would be beneficial; however, the data does not support that theory. When considering the performance metric *user percent unoccluded*, the main factor that improved operators' performance was the dedicated sensor screens. This data does not support hypothesis h1or h3 (obstruction information would improve operators' performance). Hypothesis h2 postulated that the timeline would remove or reduce the need for the dedicated screen, but we did not see that at all. When looking at the transition counts, which may be an indication of the operators' workload, we see no benefit of providing the participants with the obstruction information; in fact we see an opposite effect. The question is 'Why did we see this?'

We think that the main reason providing obstruction information did not help operators is that the database for our environment contained noisy information. In order to determine if a sensor is being blocked or not, the operator needs a detailed database of the environment. In our experiments we had such a database; however, it did not account for architectural details (e.g., awnings) or other attributes in the environment such as trees or vehicles. These minor omissions from the database would cause the obstruction information driving the timeline to be incorrect, which would in turn lead the participants to not trust the timeline. In conclusion, the data from previous and current research suggests augmented reality rays improve operators' performance when maintaining persistent stare with multiple sensors. One caveat to this research is that all of the tasks took place in an urban environment with straight and either parallel or perpendicular streets, possibly helping the operators in unforeseen ways. The number of RPAs an operator is controlling also influences the utility of augmented reality. In addition, the data suggests that providing obstruction information is not beneficial. Future researchers will examine the appropriate size for the dedicated sensor screens and begin to look at how to employ this technology on mobile devices.

Publications

Venero, P, Rowe, A. & Boyer, J. (2013) *Information Management for Multiple Entities in a Remote Sensor Environment.* Paper presented at Human Computer Interaction International, Las Vegas, NV.

2.3.5 Mobile Vantage

Experiment Particulars

This study builds upon the work of Venero, et al. to determine the optimum number of RPA sensors (2, 4 or 6) an operator can monitor with and without rays. While the previous study used a desktop monitor and mouse, this study will be conducted on the mobile, touch-operated Samsung Slate.

Discussion

The hypothesis for this experiment was that the ray conditions will outperform the non – ray conditions in every scenario save the trials with 2 RPAs. As the workload, or number of sensors, increases, so will the operator's reliance on ray augmentation. The results showed an increase in performance in the 4 vehicle condition when the participants had the rays. Performance was the same with or without rays in the 2 and 6 vehicle conditions.

Publications

Rowe, A., Venero, P., & Boyer, J. (2013, June) *Incorporating Augmented Reality into a Tablet Interface for the Exploitation of Multiple Sensor Feeds*. Paper presented at Military Operations Society Symposium, Alexandria, VA.

2.3.6 Continual Understanding of Elevation Separation (CUES) Study

Introduction

The current state-of-the-art for Remotely Piloted Aircraft (RPA) to maintain situational awareness is the Tactical Situation Display (TSD). The TSD relies on symbols, icons, and dynamic glyphs overlaid on different types of maps, satellite imagery and to represent air traffic in the area of interest. This set-up has many limitations, one of which being that it is a 2-dimensional representation of 3-dimensional information. This is a particularly vexing issue as it limits operators' ability to use the TSD for deconfliction of airspace. This is mainly because RPA operators use altitude as their main method of deconfliction. Limited camera views and numeric representations of altitude make it hard to see other aircraft and delineate between whether or not they are roughly at the same Mean Sea Level (MSL). The 711th Human Performance Wing Supervisory Control Interfaces Branch (711 HPW/RHCI) is researching the use of preattentive cues to maintain operator awareness of aircraft relative to the one under control. These cues would be simple, yet salient, to allow for quick reference for efficient and reliable deconfliction. RHCI will test various methods of representing altitudinal differences with respect to one's aircraft by changing the opacity, size, texture, and enclosure (shape around the aircraft marker) to investigate their value of portraying this critical information. In ths way, RPA operators would need only to look at the TSD and note which aircraft are at the same flight level; a far simpler task when compared to the current method of looking at numeric altitudes and comparing them to one's own. The goal of this study is to determine the most effective way to represent differences between aircraft altitudes relative to one under control to allow for easier airspace deconfliction.

Methods

The evaluation involved 10 participants who completed a 75-question test. The test consisted of 5 trials (one per condition) that had 15 questions each. The 15 questions were divided into 3 sets. The first set of questions asked which aircraft were on the same level as that of the participant while only showing symbols that represented aircraft being on or above his/her altitude. The second asked which aircraft were on the same level as that of the participant while showing symbols that represented aircraft being below, above, or on his/her altitude. The second asked which aircraft were above the participant's flight level while showing symbols that represented aircraft being below, above, or on his/her altitude. The symbols were arranged in an 8 X 6 grid (no lines) on a gray background. The answer sheet was a corresponding grid with grid lines and points (pencil and paper). The participants encountered slides that would appear for 3 seconds and then go blank. They would then circle the symbols on the paper grid relative to the ones on the screen. Grading assessed the participants' accuracy in noting the target symbols'

Discussion

The results of this evaluation provide for recommendations and future areas of study. In all cases, opacity performed well. Symbol size also contributed to good performance. Most of the participants posited that a combination of opacity and size at any level might enable the best degree of saliency. Altogether opacity would most likely be the best representations of altitude separation. This method worked very well for representing higher and lower altitudes as well as being salient enough for showing which aircraft are on the same level. Further investigation is warranted in this area to establish better guidelines and practices. Brightness and texture could be implemented better to see if they have any benefits. The hostile symbols could be evaluated to determine why they were marked less frequently. This could be of importance as it would be impractical to have operators not notice dangerous entities. Finally these symbols should be analyzed overlaid on a map or TSD while moving.

Publications

None

2.3.7 Strategies for Maintaining Awareness of Related Targets (SMART)

Introduction

This study was aimed at evaluating methods to represent multiple moving and stationary targets for recall accuracy.

Methods

Participants had to briefly watch a screen with multiple homogenous points and then recall their locations and the direction of movement for moving targets. A "no aid" condition was used as the baseline. Test implementations included bars drawn in the direction of movement on moving icons and drawing lines between icons to create polygons so that participants could remember shapes instead of points. Participants' performance was measured in terms of accurately stating how many icons there were and marking the icons' locations on a grid. Analyses gave each participant a score.

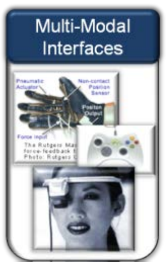
Discussion

The condition where bars were drawn in the direction of movement enabled significantly better performance, while being rated most favorably by participants. The polygon condition was rated least favorably and significantly decreased participants' recall performance. Future implementations should likely try to use directional bars with color, texture, or opacity cues.

Publications

None

2.4 Multi-Modal Interactions



Because of intense information load, visual clutter, and awkward input methods, a pilot can only control one UAV at a time the multi-modal set of studies seek create an intuitive interface such that one pilot can successfully monitor and manage multiple UAVs

2.4.1 Determination of Efficiency for a Variety of Input Control Equipment (DEVICE) Study

Introduction

The objective of this study was to investigate the effectiveness of several multi-modal input devices as alternatives to the standard mouse for simple computer screen movements and interactions common to supervisory control of multiple Remotely Piloted Aircraft (RPAs) and to develop human-system interface design recommendations to enable efficient and effective performance. The devices were 1) standard mouse, 2) Belkin n52te, 3) Saitek Cyborg Command Unit, 4) Wacom Bamboo Fun with Stylus, 5) Wacom Bamboo Fun with Touch, and 6) Xbox 360 Controller. Participants performed 4 tasks with each device: neutral point movement, dragging, tracking, and zooming. Participants' self-reported level of experience varied among the devices.

Methods

Participants were 12 civilian and military personnel stationed at Wright-Patterson Air Force Base, OH. The sample consisted of 6 men and 6 women. Ten of the 12 participants were between 18-25 years of age and 2 were between 26-35 years. Participants were required to have normal visual acuity (20/20) or corrected-to-normal visual acuity in both eyes and normal color vision. Visual acuity and color vision were determined by self-report. Participation was voluntary; no compensation was offered for participation in this study.

The study began with a briefing regarding the study objectives and completion of the informed consent form and biographical data collection. During the course of the experiment, each participant performed 4 tasks (neutral point movement, tracking, dragging, and zooming) with each on the 6 devices. The order of the devices varied across participants. However, the order of the tasks was the same for each device. Participants were allowed to train with each device/task combination until they indicated they were comfortable with the task and input device. Following practice, participants completed several test trials for each task/device combination, then completed a post-device questionnaire regarding the utility of the device for performing each task and their comments regarding the strengths and weaknesses of that device. This procedure was followed until each of the devices had been evaluated. On completion of the test trials, participants completed the post-study questionnaire.

Discussion

Paired samples t-tests indicated that subjects were more familiar with the standard mouse and keyboard than any of the other devices. Task performance was measured by average response time across trials for the neutral point movement, dragging, and zooming tasks. Task performance for the tracking task was measured by average root mean square error across trials. Sixteen of the 20 comparisons between the standard mouse and the other five devices were statistically significant. In all instances where the difference was statistically significant, the standard mouse outperformed the other devices (i.e., lower response time, smaller RMS error). Although results strongly favored the standard mouse, the researchers note the need for additional studies under more realistic conditions to determine the generalizability of the results.

Publications

Aldridge, A.C., Newman, M.R, Carretta, T.R, Rowe, A.J, French, G.A., & Whalen, J.P., (2012). Supervisory Control Information Management Research (SCIMR) Studies: Determination of Efficiency for a Variety of Input Control Equipment (DEVICE), AFRL-RH-WP-TR-2012-0050. Wright-Patterson AFB, OH: Air Force Research Laboratory, Human Effectiveness Directorate, Crew Systems Interface Division, Supervisory Control Interfaces Branch.

2.4.2 Study of Hotkey Operation Relative to Touch Commands in Utility Tasks (SHORTCUT)

Introduction

Determine performance characteristics for gesturing and gaming input control compared to current findings for accepted input device efficacy (DEVICE) to aid in development of input methods for a full control station and a Man-portable control system. Independent variables- Method of input (mouse, *Bamboo with stylus*, mouse with gaming keyboard, and multi-touch); Dependent variables- Performance measured in numbers of errors and time of completion for a relatively complex maze and side task set-up. Methods: 30-40 Participants, 4 Input methods, 2 Mazes (Go forward and back), Post trial and post session, Between groups design, 30 Mins per session.

Methods

Participants included 30 Civilian and military employees located at Wright-Patterson AFB, OH. After examination of the data, 2 participants were removed from the analyses due to extreme scores on their response times. The sample consisted of 18 males and 10 females. They were placed in age groups, with 16 participants between 18 and 25 years of age, 8 participants between 26 and 35 years of age, 1 participant between 36 and 45 years of age and 2 participants who were 45 years of age or older. Both were in the Touch device condition. Participants were required to have normal vision (20/20) or corrected-to-normal vision in both eyes and normal color vision. Visual acuity and color vision were determined by participant self report.

Each session began with a briefing regarding the study objectives and completion of the informed consent document and demographic questionnaire. Following the introduction, participants underwent training for their respective devices. Participants trained until they met the requirements to proceed to the trial mazes. During the course of the data collection, participants completed 2 trials, one with a spiral and one with an N-shaped maze. Each trial was defined by a maze task combined with a set of 5 secondary tasks. The sequence of events was the same for all participants, but the maze order was counterbalanced, meaning that every other participant received the spiral maze before the N maze. Following each trial, participants completed a NASA TLX for that maze. At the conclusion of both trials, participants completed a post-session questionnaire. The entire session required an average of an hour including the introductory briefing, informed consent, training, two mazes, and questionnaires.

At the test station, each participant received detailed training in all of the procedures to be employed during the entire experiment. First, participants were given an introductory briefing on the primary and secondary tasks to include a description of objectives, feedback mechanisms, and performance analysis methods. Training progressed from proving proficiency with each individual task (encompassing all of the maze actions and the secondary tasks outlined in the “Mapping” section) to small task sequences (i.e., change color then engage shield) and, ultimately, performing primary (maze) actions and secondary tasks simultaneously. Participants were prompted by on-screen text instructions. They attempted each task/action until it was performed correctly 5 times in a row, or until a minimum success rate of 70% out of 10 trials was achieved. If this success rate was not achieved in the first 10 trials, participants continued attempting the task/action until the success rate increased to 70% or the task/action was performed correctly 5 times in a row.

Prior to the beginning of each trial, there was a screen prompting “Click to begin trial”. Clicking caused the maze to appear. After a three second countdown, (visually represented in the center of the screen) which allowed the participants to quickly familiarize themselves with the maze’s layout, the participants were able to interact with the maze and the timers began.

The task set involved successfully completing a maze that had obstacles to overcome and objectives which participants had to accomplish. The maze was on the left side of the monitor and additional, secondary tasks were performed on the right. Maze completion was dependent upon successfully accomplishing all prescribed tasks while still reaching the end.

The primary task was a maze on the left side of the screen. Completion of the maze involved overcoming obstacles with the use of assigned gestures, hotkeys, or menus, as well as completing secondary tasks on the right side of the screen with the main device. Secondary tasks did not have to be performed immediately and could have been stacked in a queue. Bimanual coordination was encouraged by putting a limit on the number of secondary tasks available for completion; if the queue reached five tasks, participants were unable to make progress in maze completion until a secondary task was performed, preventing them from focusing solely on the primary task.

Designs for primary and secondary tasks were derived from integrating Fitts’ law and steer point analysis in conjunction with a test created by Armbrüster et al. (2007). Other design considerations were derived from contemporary and foreseeable multi-RPA supervisory control and sensor management environments.

Discussion

There were no significant differences between the mouse with Belkin n52te and the standard mouse, but the mouse with Belkin n52te trended better than the standard mouse alone in maze completion time, reactions to stimuli, and error rates. The multi-touch functionality was significantly worse than the mouse with Belkinn52te and provided many lessons learned. The researchers identified the need for more flexible gesture recognition, should complex gestures be used. The optimal method for utilizing multi-touch in its current state, however, is to use simple, single-finger inputs to ensure higher accuracy and lower fatigue and frustration.

Publications

Aldridge, A.C., Newman, M.R, Carretta, T.R, Rowe, A.J, French, G.A., & Whalen, J.P., (2012). Supervisory Control Information Management Research (SCIMR) Studies: Study of Hotkey Operations Relative to Touch Commands in Utility Tasks(SHORTCUT), AFRL-RH-WP-TR-2012-0168. Wright-Patterson AFB, OH: Air Force Research Laboratory, Human Effectiveness Directorate, Crew Systems Interface Division, Supervisory Control Interfaces Branch.

2.4.3 Surveilling an Urban Populous Area with a Robust Monitoring Asset Network (SUPARMAN)

Introduction

The objective of this research is to identify the best input techniques for managing an urban electro-optical sensor network with a single user. The first study in what should be a series will build off of the VOICE research and evaluate the performance gains using speech to augment multi-touch. In this case, as with VOICE, vocal input used concurrently with touch will be assessed in comparison to touch alone. The participants will have at their command 20 fixed urban security cameras as well as a remotely piloted aircraft sensor gimble. The task set will involve identifying a target in a densely populated simulated city, tracking the target, and capturing still images of the target as he/she moves throughout the city.

Methods

This study will require 20 participants. The subject pool will be limited to members of the U.S. Air Force, U.S. DoD civilian employees, U.S. DoD contractors, other Armed Services units, and paid volunteers. Participants are required to have normal vision (20/20) or corrected-to-normal vision in both eyes, normal peripheral vision, and normal color vision. Visual acuity and color vision will be determined by subject self report (in response to the invitation). This study will use a within groups design in which the two scenarios and configurations will be counterbalanced to prevent expectancy errors. Screening for gender or a specific male/female ratio will be administered for a 50/50 split. Participants must be 18 years old or older.

Participants will first be asked to identify the target in a simulated urban environment. The simulated environment will be replete with people and automobiles. The basic description of the target will match the visual representations of 5 simulated people among the city's population.

The target will be identified when he or she stops and looks at his/her watch. Until that action occurs, the participants will have to find and then monitor all five potential targets. Participants will have around 6 minutes to identify and track potential targets before the actual target performs the specified action. When the participants identify the target, they will then select and manipulate the appropriate sensors to maintain coverage while capturing images when required.

After 8 minutes of tracking the walking target, he/she will begin to run on a generated path. The participants will have to then maintain coverage on the faster moving target. After a few more minutes, the target will enter a vehicle and the participants will have to track that vehicle as it moves considerably faster. To aid the participant, radio calls will come from simulated human agents on the ground that will announce possible sightings. These radio calls will be correct 80% of the time.

Along with tracking, participants will have the task of capturing still images (via the main sensor window) of three important events. These events are: the target checking his/her watch, picking up an object, entering a vehicle, and exiting the area of regard. Participants will be given direction to attempt to catch these actions in progress for evidence.

Discussion:

The data collected showed that overall the interface layout is user-friendly. Touch was found to be more intuitive than speech. Voice commands would make the task easier to perform if more exposure was given to the commands prior to task execution. Voice commands often had to be repeated (speech software not always accurate), which wasted time and increased workload. A speech-driven HMI would be distracting to others in the actual work environment and would complicate parsing. A physical joystick would be more intuitive for sensor window functions (pan/tilt/zoom). Providing both an exo and ego viewpoint, the “touched point” feature, the Sensor Window Dock, field agent calls (linked to map) all helped maintain SA and increased time on target.

Publications

Roll, J., Lampke, S. & Adkins, D. (2013, June) *Surveillance of an Urban Populous Area with a Robust Monitoring Network of Sensor Assets*. Paper presented at Military Operations Society Symposium, Alexandria, VA.

3.0 CONCLUSIONS

Unmanned aerial systems (UAS) are becoming an increasingly critical aspect of military operations. To meet this demand, the USAF is seeking ever more capable UASs, to include the ability of a single operator to simultaneously control multiple platforms, increased connectivity to net-centric information sources, and the ability to accomplish more complex, dynamic missions. These capabilities include:

1) close collaboration with manned assets
2) find, fix, track, and target difficult targets in complex urban and difficult terrains
3) destroy or neutralize difficult targets

4) precisely deliver select effects to maintain controllable collateral damage
5) persistence in multiple areas of interest

To fulfill these missions, the USAF is exploring multi-vehicle UAS concepts to carry out tactical intelligence, surveillance, reconnaissance and combat missions. In many of these concepts there is an emphasis on managing UAS systems and conducting missions with minimal crew. UASs have evolved from being primarily remotely controlled systems to being pre-programmed or semi-autonomous, changing the role of the crew from flying to supervising. This change has opened the door to increasing the vehicle to operator ratio. While progress has been made in developing more capability with multi-vehicle systems (e.g., more simultaneous vehicle orbits managed from one control station), further research is needed to increase mission effectiveness on per vehicle and per operator basis. To increase mission effectiveness, crew performance and capability enhancements are needed. Technology development and advanced designs are required to facilitate more timely and effective operator situation assessment and decision-making.

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